United States
Environmental Protection
Agency

Health Effects
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA/600/S1-86/006 Dec. 1986

EPA

Project Summary

Effects of 60-Hz Fields on Human Health Parameters

Mary R. Cook, Carl M. Maresh, and Harvey D. Cohen

Research on the effects of exposure to 60-Hz electric and magnetic fields has provided contradictory evidence for both increases and decreases in physiological and metabolic functioning, and specific results have often been difficult to replicate. If biological responses to powerline fields occur, they are undoubtedly subtle, and research strategies must be specifically designed to enhance and clarify subtle effects.

The study reported here used quantitative exercise testing techniques to evaluate whether increases in metabolism, caused by moderate steady-state exercise prior to exposure to real or sham fields, would clarify potential field effects.

This research showed that physical recovery processes following moderate steady-state exercise were the same in real and sham fields. Of the variables examined, only heart rate (cardiac interbeat interval) was altered by 2 hr of field exposure. A small, statistically significant decrease in heart rate (3 beats/min) was found when subjects were exposed to the real field after sitting quietly prior to exposure. This replicates our earlier research, in which heart rate showed a similar decrease after a total of 6 hr of field exposure. The results suggest that future studies should examine a broader range of the continuum of human arousal and physiological activation.

This Project Summary was developed by EPA's Health Effects Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Public concern has been expressed about possible health risks arising from exposure to the electric and magnetic fields generated by overhead power transmission lines. Previous research results have often been contradictory and difficult to replicate, suggesting that field effects, if real, are subtle. Furthermore, the literature suggests that 60-Hz fields might interact with neural mechanisms important in the control of levels of arousal. Research strategies specifically designed to elucidate subtle effects are needed, and such strategies should be used to directly investigate the effects of field exposure over the continuum of human arousal.

Quantitative exercise testing techniques have been quite helpful in improving the understanding of mechanisms associated with adaptation to other environmental conditions. Controlled exercise can be used to raise physiological and metabolic function to a higher level; at this higher level, subtle changes in function may be more apparent and therefore more easily measured. This research was based on the idea that exercise testing methods might be particularly promising in research on 60-Hz field effects, since results of previous studies on the effects of field exposure have provided support for both increases and decreases in physiological functioning, as well as for a dampening or shifting of normal circadian variations.

The research reported here had two objectives: to evaluate the efficacy of the approach by determining the feasibility of combining exercise and field exposure techniques; and to evaluate whether increases in metabolism, caused by moderate steady-state exercise prior to exposure to real or sham fields, would clarify potential field effects.

Procedures

Experimental Design

Each of eleven subjects participated in a maximal exercise test, one familiarization session, and four experimental sessions. During the four experimental sessions, which were held at weekly intervals, four conditions were presented in counterbalanced order: (1) exercise on a bicycle ergometer at 50% of VO_2 max for 45 min, followed by exposure to sham fields for 2 hr; (2) exercise followed by exposure to real fields (9 kV/m, 16 A/m) for 2 hr; (3) sitting quietly for 45 min, followed by exposure to sham fields for 2 hr; and (4) sitting quietly followed by exposure to real fields. All four sessions were conducted under double-blind conditions.

Measure of cardiac activity, rectal temperature, and biochemistry were obtained at the end of a 30-min equilibration period and during the 45-min pre-exposure period (exercise or sitting quietly). Ratings of perceived exertion also were collected at 2-min intervals during exercise. All measures except rectal temperature and perceived exertion were obtained during recovery in the real and sham fields. In addition, continuous dosimetry measures were taken throughout exposure. At the end of each session, both the experimenter and the subject judged whether the real or sham fields had been presented.

Exposure Facility and Double-Blind Control System

The exposure room is positioned inside a parallel plate system. A set of capacitively coupled, copper gradient rings is located behind the walls to increase field uniformity. The magnetic field is generated by six Helmholtz coils, surrounding the room in both the vertical and horizontal axes. Dedicated equipment is used to maintain ambient temperature and relative humidity at controlled levels, and the exposure area is continuously monitored from two adjacent control rooms via closed-circuit television and audio intercommunication equipment. Uniform electric and magnetic fields can be generated in the subject test area (0-16 kV/m, ± 5.6%; 0-32 A/m, ± 4.8%). The vertical axis of the magnetic field is in phase with the electric field, and the horizontal axis is phase shifted 90° with the electric field. Additional equipment provides continuous monitoring of electric and magnetic field status, and individual short circuit current (Isc) throughout the exposure period. During exposure periods in this study the E field was set at 9 kV/m and the magnetic field components set at 16 A/m.

The double-blind experimental control system allows presentation of real and sham fields without either the subject or the experimenters being aware of which field condition is in effect at any given time. Experimenters are kept unaware of exposure conditions through a system of hardware and software interlocks under the control of a master computer program. The interlocks blank, mask, or disguise all field-related cues in the control room equipment.

Our previous research indicated that subjects could often perceive the fields when they raised their hands in the air. The double-blind system was designed to counteract this major perceptual cue. It uses the continuous Isc monitoring circuit to detect arm and hand movement. Whenever continuous Isc exceeds an individually set reference value, the strength of the electric field is immediately decreased by 75% for 30 sec, and then gradually returns to the original 9 kV/m level. When the original level is attained, the Isc comparison is again made. If the hands are still raised, field strength again decreases; if Isc is below the reference value, field strength continues to be maintained at 9 kV/m. Once an experimental session is started, operation of the double-blind system is completely automatic.

Subjects

Twelve men between 21 and 29 years of age volunteered to participate in the study, but only 11 subjects completed all of the experimental sessions. All were in good health and had not participated during the past year in a formal aerobic conditioning program. Each subject's daily activity pattern remained consistent throughout the duration of the study. After a complete and accurate verbal description of the procedures, risks, and benefits associated with the study, each subject provided written informed consent. Subjects were paid for their participation.

Maximal Exercise Test

In addition to measuring each subject's aerobic power, the maximal exercise test was designed to determine the workload and heart rate that most closely corresponded with 50% of the $\dot{V}O_2$ max. Metabolic measurements were assessed using a breath-by-breath system. The subject wore a Hans-Rudolph respiratory mask (Hans Rudolph, Incorporated) connected to a Medical Graphics Wave-Form analyzer (Medical Graphics Corporation); O_2 and CO_2 percentages were determined using a Perkin-Elmer MGA 1100 mass spectrometer.

The subject cycled continuously on a bicycle ergometer (Monark A.B.) at 60 rpm beginning with a 2-min workload of 0 $kgm \cdot min^{-1}$ followed by incremental increases of 180 $kgm \cdot min^{-1}$ every 3 min until volitional exhaustion. To ascertain that $\dot{V}O_2$ max had been attained, each subject was required to meet at least three of the following criteria: (1) no further increase in oxygen uptake, despite an increase in workload (plateau criterion); (2) attainment of the age-predicted maximal heart rate; (3) a respiratory exchange ratio ($\dot{V}CO_2/\dot{V}O_2$) greater than 1.10; and (4) a blood lactic acid value of at least 8 $mM \cdot L^{-1}$ at 4 min after exercise.

Experimental Sessions

When a subject arrived at the laboratory, he changed into a sweatsuit and cotton socks. Electrodes for recording heart rate were attached, a rectal temperature probe inserted, and a 20-gauge cannula maintained patent with a heparin lock inserted into a forearm vein. After a 30-min equilibration period, a blood sample was drawn; the standardized 45-min exercise/no-exercise period then began. Under the no-excercise condition, the subject sat quietly reading for the remainder of the period. Under exercise conditions, the subject cycled continuously (60 rpm) at appropriately adjusted workload settings to maintain the desired 50% of his previously determined $\dot{V}O_2$ max. Heart rate and core temperature were monitored, and differentiated ratings of perceived exertion were recorded every 5 min. A 3-mL blood sample was drawn via the cannula after 30 min of exercise for measurement of lactic acid. Prior to conclusion of the exercise test, another blood sample was drawn for measurement of all blood variables. Identical physiological and biochemical measures were obtained under the no-exercise condition, except that the 30-min lactate sample was not required.

After the exercise period, the subject

immediately entered the exposure facility. The rectal probe and the subject's shoes were removed, the subject put the sweatshirt back on, and the electric field dosimetry "ground" was attached to both ankles. This transition required approximately 2 min. The real or sham field was then activated by initiating the computer program. Cardiac measures were obtained continuously during the exposure period. Blood pressure and blood samples for all blood variables were obtained at 10, 30, 60, 90, and 120 min after exercise. Approximately 2 min of field deactivation was required each time blood pressure readings and blood samples were obtained.

Results

The first goal of statistical analysis was to verify that the conditions specified in the experimental design were met. No difference in temperature or humidity was found between real and sham exposure days. Subjects were unable to distinguish between real and sham conditions at better than chance levels. All subjects met criteria for maximal exercise tests, and increased metabolic steady-state was associated with the 45-min exercise regimen.

Analysis of Experimental Variables

Each dependent measure was submitted to three analyses. The first addressed the question of whether exercise, as compared to sitting quietly, altered the measure significantly. The other two analyses examined exercise and no-exercise conditions separately to determine whether exposure to 60-Hz fields had a significant effect. This strategy was chosen since a major hypothesis was that any field effects observed would show higher levels of statistical significance after exercise. Data at 10, 30, 60, 90, and 120 min from the end of the exercise or resting period were used for these analyses. An effect was considered to be statistically significant if probability was .05 or less. The Greenhouse-Geisser correction was used to adjust for inflated degrees of freedom due to repeated measures.

Although exercise produced the expected changes in the physiological and biochemical measures, the variables were not different under real and sham field conditions subsequent to exercise. However, when subjects rested quietly prior to exposure, heart rate was slower during exposure to the real fields than during exposure to sham fields. Comparison between heart rate at the end of the first 10 min of exposure and after 120 min of exposure indicated that, on real field exposure days, subjects showed a significant decrease in heart rate, while on sham exposure days no change was found. This decrease in heart rate associated with exposure to the real fields occurred for 9 of the 11 subjects; the magnitude of the change was correlated with total exposure to the electric field as measured with short circuit current ($r = .49$, df 9, $p < .10$). No other differences in response between real and sham field exposure were found.

Conclusions and Recommendations

The feasibility of the methods and procedures used was clearly established. Exercise at 50% of maximal oxygen uptake produced the expected changes in plasma volume and in hormone, electrolyte, and lactic acid levels. When subjects were subsequently exposed to real and sham fields, the double-blind control procedures used were effective in preventing the subjects from distinguishing between the two conditions at better than chance levels. If subjects sat quietly instead of exercising during the preexposure period, heart rate significantly decreased during subsequent exposure to the real fields. This phenomenon was also observed in our previous study of field exposure effects. However, the use of moderate, steady-state exercise prior to exposure did not serve to clarify field effects. The recovery process was the same under real versus sham exposure conditions.

These results suggest that future work should focus on evaluation of the effects of 60-Hz fields on the entire process of exercise-induced activation and recovery (pre-exercise, exercise, and recovery). Ideally, such studies should: (1) contrast exercise results with results obtained after periods of very low physiological arousal; (2) vary the duration of exposure to fields before exercise; and (3) examine the effects of different intensities of exercise in the fields.

Mary R. Cook, Carl M. Maresh, and Harvey D. Cohen are with Midwest Research Institute, Kansas City, MO 64110.
***Carl F. Blackman** is the EPA Project Officer (see below).*

The complete report, entitled ***"Effects of 60-Hz Fields on Human Health Parameters,"*** *(Order No. PB 86-231 297/AS; Cost: $11.95, subject to change) will be available only from:*

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:
Health Effects Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300

EPA/600/S1-86/006